IN PARTNERSHIP WITH:
CNRS

Université Rennes 1

Université Haute Bretagne (Rennes 2)

Activity Report 2011

Team MIMETIC

Analysis-Synthesis Approach for Virtual Human Simulation

RESEARCH CENTER
Rennes - Bretagne-Atlantique

THEME
Interaction and Visualization

Table of contents

Team MIMETIC

Keywords: Virtual Human, Virtual Reality, Simulation, Computer Graphics, Perception

1. Members

Research Scientists

Stéphane Donikian [Habilité, HdR]
Julien Pettré [Research Scientist]

Faculty Members

Franck Multon [Team Leader, Professor Univ. Rennes 2, HdR]
Benoit Bideau [Associate Professor Univ. Rennes 2]
Nicolas Bideau [Associate Professor Univ. Rennes 2]
Marc Christie [Associate Professor, Univ. Rennes 1 (from Oct 2011)]
Armel Crétual [Associate Professor Univ. Rennes 2, HdR]
Fabrice Lamarche [Associate Professor, Univ. Rennes 1]
Guillaume Nicolas [Associate Professor Univ. Rennes 2]
Richard Kulpa [Associate Professor Univ. Rennes 2]

Technical Staff

Emmanuel Badier
Julian Joseph
Orianne Siret
Sébastien Maraux
Thomas Robert

PhD Students

Thomas Lopez [MNERT Grant]
Antoine Marin [Biofeedback project]
Sébastien Brault [ENS Cachan grant]
Anthony Sorel [Cifre convention with Artefacto company]
Christophe Lino [IRIS project and co-supervision with U. Newcastle]
Edouard Auvinet [Cifre convention and co-supervision with U. Montreal]
Anne-Marie Burns [Biofeedback project]
Caroline Martin [ENS Cachan grant]
Samuel Lemercier [Pedigree project]
Jonathan Perrinet [Tango project]
Philippe Rannou [ENS Cachan grant]
Yijiang Zhang [French Embassy in China grant]
Carl-Johan Jorgensen [iSpace & Time project]

Post-Doctoral Fellows

Yi Li [INRIA Grant]
Anne-Hélène Olivier [Tango grant]

Administrative Assistants

Céline Gharsalli
Nathalie Denis

2. Overall Objectives

2.1. Introduction

MimeTIC is a multidisciplinary team which aim is to better understand and model human activity in order to simulate realistic autonomous virtual humans: realistic behavior, realistic motions and realistic interactions with other characters and users. It leads to modeling the complexity of human body, his environment where he cans pick-up information and he can act on it. A specific focus is dedicated to human physical activity and sports as it raises the highest constraints and the highest complexity when addressing these problems. Thus, MimeTIC is composed of experts in computer science who were members of Bunraku team (INRIA team ended in December 2010) and whose research interests are computer animation, behavioral simulation, motion simulation, crowds and interaction between real and virtual humans. MimeTIC is also composed of experts in sports science, motion analysis, motion sensing, biomechanics and motion control (M2S, joint lab. with University Rennes2, ENS Cachan and University Rennes1). Hence, the scientific foundations of MimeTIC are motion sciences (biomechanics, motion control, perception-action coupling, motion analysis), computational geometry (modeling of the 3D environment, motion planning, path planning) and design of protocols in immersive environments (use of virtual reality facilities to analyze human activity).

Thanks to these skills, we wish to reach the following objectives: to make virtual human behave, move and interact in a natural manner in order to increase immersion and to improve knowledge on human motion control. In real situations (see figure 1), people have to deal with their physiological, biomechanical and neurophysiological capabilities in order to reach a complex goal. Hence MimeTIC addresses the problem of modeling the anatomical, biomechanical and physiological properties of human being. Moreover this character has to deal with his environment. Firstly he has to perceive this environment and pick-up relevant information. MimeTIC thus address the problem of modeling the environment including its geometry and associated semantic information. Secondly, he has to act on this environment to reach his goal. It leads to cognivitve processes, motion planning, joint coordination and force production in order to act on this environment.

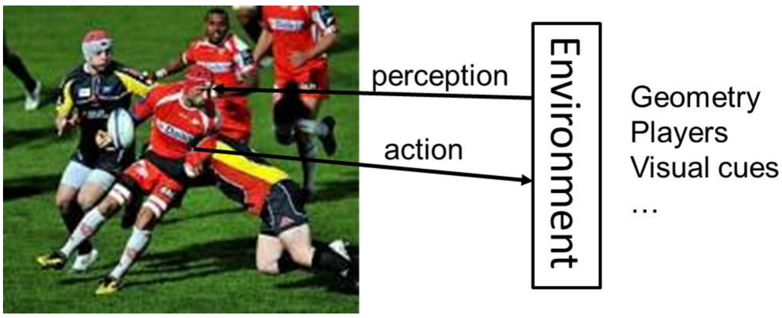

Figure 1. Main objective of MimeTIC: better understand human activity in order to better simulate virtual humans. It leads to modeling the complexity of human body, his environment where he cans pick-up information and he can act on it.

In order to reach the above objectives, MimeTIC has to address three main challenges:

- dealing with the intrinsic complexity of human being, especially when addressing the problem of interactions between people for which it's impossible to predict and model all the possible states of the system,
- making the different components of human activity control (such as the biomechanical and physical, the reactive, cognitive, rational and social layers) interact while each of them is modeled with

completely different states and time sampling,

- and being able to measure human activity while dealing with the compromise between ecological and controllable protocols, and to be able to extract relevant information in wide databases of information.

Contrary to many classical approaches in computer simulation which mostly propose simulation without trying to understand how real people do, the team promotes a coupling between human activity analysis and synthesis, as shown in figure 2.

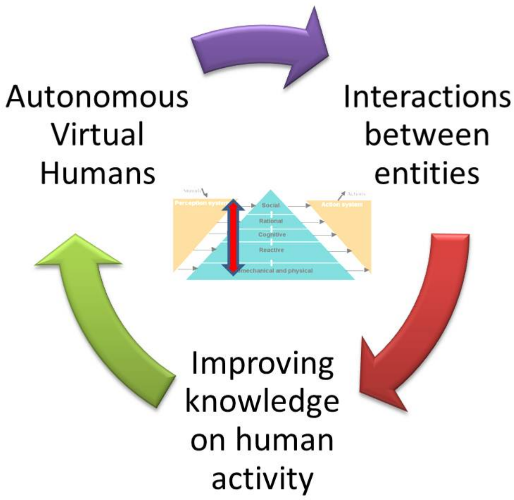

Figure 2. Research path of MimeTIC: coupling analysis and synthesis of human activity. Analysis provides us with more realistic autonomous characters and synthesis enables us to evaluate assumption about human motion control.

In this research path, improving knowledge on human activity enables us to highlight fundamental assumptions about natural control of human activities. These contributions can be promoted in biomechanics, motion sciences, neurosciences, *etc.* According to these assumptions we propose new algorithms for controlling autonomous virtual humans. The virtual humans can perceive their environment and decide of the most natural action to reach a given goal. This work is promoted in computer animation, virtual reality and has some applications in robotics through collaborations. Once autonomous virtual humans have the ability to act as real humans should do in the same situation, it is possible to make them interact with other autonomous characters (for crowds or group simulations) and with real users. The key idea here is to analyze to what extent the assumptions proposed at the first stage lead to natural interactions with real users. This process enables the validation of both our assumptions and our models.

Among all the problems and challenges described above, MimeTIC focuses on the following domains of research:

- motion sensing which is a key issue to extract information from raw motion capture systems and thus to propose assumptions on how people control their activity,
- human activity & virtual reality, which has been explored through sports application in MimeTIC, enables us to design new methods for analyzing the perception-action coupling in human activity, and to validate whether the autonomous characters lead to natural interactions with users,

- crowds and groups simulation which is dedicated to model the interactions in small groups of individuals and to see how to extend to larger groups, such as crowds with lot of individual variability,
- virtual Storytelling which enables us to design and simulate complex scenarios involving several humans who have to satisfy numerous complex constraints (such as adapting to the real-time environment in order to play an imposed scenario), and to design the coupling with the camera scenario to provide the user with a real cinematographic experience,
- biomechanics which is essential to offer autonomous virtual humans who can react to physical constraints in order to reach high-level goals, such as maintaining balance in dynamic situation or selecting a natural motor behavior among all the theoretical solution space for a given task,
- and Autonomous Characters which is a transversal domain that can reuse the results of all the other domains to make these heterogeneous assumptions and models provide the character with natural behaviors and autonomy.

2.2. Highlights

- Accepted papers in major venues:
  - *"Imperceptible Relaxation of Collision Avoidance Constraints in Virtual Crowds"* accepted at ACM Siggraph Asia 2011 (acceptance rate 17%) [4]
  - *"The Director's Lens: An Intelligent Assistant for Virtual Cinematography"* accepted at ACM Multimedia 2011 (acceptance rate 17%) [16]
- Organization of the Symposium "Simulation of Sports Motions" co-located with CASA in Cheng-du, China (May, 26-28 2011).

3. Scientific Foundations

3.1. Biomechanics and Motion Control

Human motion control is a very complex phenomenon that involves several layered systems, as shown in figure 3. Each layer of this contoller is responsible for dealing with perceptual stimuli in order to decide the actions that should be applied to the human body and his environment. Due to the intrinsic complexity of the information (internal representation of the body and mental state, external representation of the environment) used to perform this task, it's almost impossible to model all the possible states of the system. Even for simple problems, there generally exist infinity of solutions. For example, from the biomechanical point of view, there are much more actuators (i.e. muscles) than degrees of freedom leading to infinity of muscle activation patterns for a unique joint rotation. From the reactive point of view there exist infinity of paths to avoid a given obstacle in navigation tasks. At each layer, the key problem is to understand how people select one solution among these infinite state spaces. Several scientific domains have addressed this problem with specific points of view, such as physiology, biomechanics, neurosciences and psychology.

In biomechanics and physiology, researchers have proposed hypotheses based on accurate joint modeling (to identify the real anatomical rotational axes), energy minimization, force and torques minimization, comfort maximization (i.e. avoiding joint limits), and physiological limitations in muscle force production. All these constraints have been used in optimal controllers to simulate natural motions. The main problem is thus to define how these constraints are composed altogether such as searching the weights used to linearly combine these criteria in order to generate a natural motion. Musculoskeletal models are stereotyped examples for which there exist infinity of muscle activation patterns, especially when dealing with antagonist muscles. An unresolved problem is to define how using the above criteria to retrieve the actual activation patterns while optimization approaches still lead to unrealistic ones. It still is an open problem that will require multidisciplinary skills including computer simulation, constraint solving, biomechanics, physiology and neurosciences.

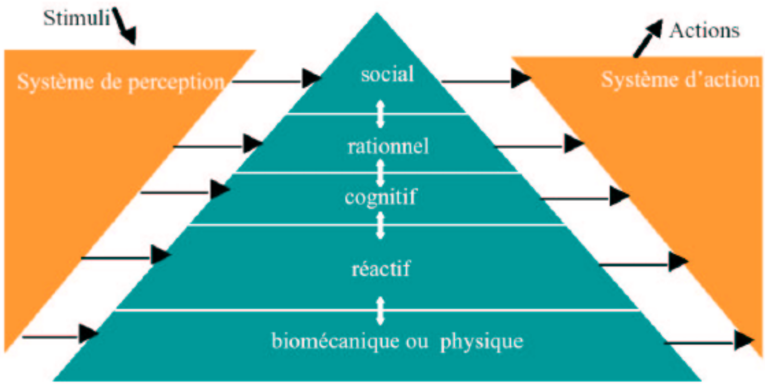

Figure 3. Layers of the motion control natural system in humans.

In neuroscience, researchers have proposed other theories, such as coordination patterns between joints driven by simplifications of the variables used to control the motion. The key idea is to assume that instead of controlling all the degrees of freedom, people control higher level variables which correspond to combination of joint angles. In walking, data reduction techniques such as Principal Component Analysis have shown that lower-limb joint angles are generally projected on a unique plan which angle in the state space is associated with energy expenditure. Although there exist knowledge on specific motion, such as locomotion or grasping, this type of approach is still difficult to generalize. The key problem is that many variables are coupled and it is very difficult to objectivly study the behavior of a unique variable in various motor tasks. Computer simulation is a promising method to evaluate such type of assumptions as it enables to accurately control all the variables and to check if it leads to natural movements.

Neurosciences also address the problem of coupling perception and action by providing control laws based on visual cues (or any other senses), such as determining how the visual flux is used to control direction in navigation tasks, while dealing with collision avoidance or interception. Coupling of the control variables is enhanced in this case as the state of the body is enriched by the big amount of external information that the subject can use. Virtual environments inhabited with autonomous characters which behavior is driven by motion control assumptions is a promising approach to solve this problem. An interesting problem in this field is navigation in an environment inhabited with other people. Avoiding static obstacles together with other people displacing into the environment is a combinatory problem that strongly relies on the coupling between perception and action.

One of the main objectives of MimeTIC is to enhanche knowledge on human motion control by developing innovative experiments based on computer simulation and immersive environments. To this end, designing experimental protocols is a key point and some of the researchers in MimeTIC have developed this skill in biomechanics and perception-action coupling. Associating these researchers to experts in virtual human simulation, computational geometry and constraints solving enable us to contribute to enhance fundamental knowleged in human motion control.

3.2. Experiments in Virtual Reality

Understanding interaction between humans is very challenging because it addresses many complex phenomena including perception, decision-making, cognition and social behaviors. Moreover, all these phenomena are difficult to isolate in real situations, it is thus very complex to understand the influence of each of them on the interaction. It is then necessary to find an alternative solution that can standardize the experiments and that allows the modification of only one parameter at a time. Video was first used since the displayed experiment is perfectly repeatible and cut-offs (stop the video at a specific time before its end) allow having temporal information. Nevertheless, the absence of adapted viewpoint and stereoscopic vision does not provide depth information that are very meaningful. Moreover, during video recording session, the real human is acting in front of a camera and not an opponent. The interaction is then not a real interaction between humans.

Virtual Reality (VR) systems allow full standardization of the experimental situations and the complete control of the virtual environment. It is then possible to modify only one parameter at a time and observe its influence on the perception of the immersed subject. VR can then be used to understand what information are picked up to make a decision. Moreover, cut-offs can also be used to obtain temporal information about when these information are picked up. When the subject can moreover react as in real situation, his movement (captured in real time) provides information about his reactions to the modified parameter. Not only is the perception studied, but the complete perception-action loop. Perception and action are indeed coupled and influence each other as suggested by Gibson in 1979.

Finally, VR allows the validation of the virtual human models. Some models are indeed based on the interaction between the virtual character and the other humans, such as a walking model. In that case, there are two ways to validate it. First, they can be compared to real data (e.g. real trajectories of pedestrians). But such data are not always available and are difficult to get. The alternative solution is then to use VR. The validation of the realism of the model is then done by immersing a real subject in a virtual environment in which a virtual character is controlled by the model. Its evaluation is then deduced from how the immersed subject reacts when interacting with the model and how realistic he feels the virtual character is.

3.3. Computational geometry

Computational geometry is a branch of computer science devoted to the study of algorithms which can be stated in terms of geometry. It aims at studying algorithms for combinatorial, topological and metric problems concerning sets of points in Euclidian spaces. Combinatorial computational geometry focuses on three main problem classes: static problems, geometric query problems and dynamic problems.

In static problems, some input is given and the corresponding output needs to be constructed or found. Such problems include linear programming, Delaunay triangulations, and Euclidian shortest paths for instance. In geometric query problems, commonly known as geometric search problems, the input consists of two parts: the search space part and the query part, which varies over the problem instances. The search space typically needs to be preprocessed, in a way that multiple queries can be answered efficiently. Some typical problems are range searching, point location in a portioned space, nearest neighbor queries for instance. In dynamic problems, the goal is to find an efficient algorithm for finding a solution repeatedly after each incremental modification of the input data (addition, deletion or movement of input geometric elements). Algorithms for problems of this type typically involve dynamic data structures. Both of previous problem types can be converted into a dynamic problem, for instance, maintaining a Delaunay triangulation between moving points.

The mimetic team works on problems such as crowd simulation, spatial analysis, path and motion planning in static and dynamic environments, camera planning with visibility constraints for instance. The core of those problems, by nature, relies on problems and techniques belonging to computational geometry. Proposed models pay attention to algorithms complexity to propose models compatible with performance constraints imposed by interactive applications.

4. Application Domains

4.1. Motion Sensing

Recording human activity is a key point of many applications and fundamental works. Numerous sensors and systems have been proposed to measure positions, angles or accelerations of the user's body parts. Whatever the system is, one of the main is to be able to automatically recognize and analyze the user's performance according to poor and noisy signals. Human activity and motion are subject to variability: intra-variability due to space and time variations of a given motion, but also inter-variability due to different styles and anthropometric dimensions. MimeTIC has addressed the above problems in two main directions.

Firstly, we have studied how to recognize and quantify motions performed by a user when using accurate systems such as Vicon (product of Oxford Metrics) or Optitrack (product of Natural Point) motion capture systems. These systems provide large vectors of accurate information. Due to the size of the state vector (all the degrees of freedom) the challenge is to find the compact information (named features) that enables the automatic system to recognize the performance of the user. Whatever the method is used, finding these relevant features that are not sensitive to intra-individual and inter-individual variability is a challenge. Some researchers have proposed to manually edit these features (such as a Boolean value stating if the arm is moving forward or backward) so that the expertise of the designer is directly linked with the success ratio. Many proposals for generic features have been proposed, such as using Laban notation which was introduced to encode dancing motions. Other approaches tend to use machine learning to automatically extract these features. However most of the proposed approaches were used to seek a database for motions which properties correspond to the features of the user's performance (named motion retrieval approaches) which doesn't ensure to retrieve the exact performance of the user but a set of motions with similar properties.

Secondly, we wish to find alternatives to the above approach which is based on analyzing accurate and complete knowledge on joint angles and positions. Hence new sensors, such as depth-cameras (Kinect, product of Microsoft) provide us with very noisy joint information but also with the surface of the user. Classical approaches would try to fit a skeleton into the surface in order to compute joint angles which, again, lead to large state vectors. An alternative would be to extract relevant information directly from the raw data, such as the surface provided by depth cameras. The key problem is that the nature of these data may be very different from classical representation of human performance. In MimeTIC, we try to address this problem in specific application domains that require picking specific information, such as gait asymmetry or regularity for clinical analysis of human walking.

4.2. VR and Sports

Sport is characterized by complex displacements and movements. These movements are dependent on visual information that the athlete can pick up in his environment, including the opponent's actions. The perception is thus fundamental to the performance. Indeed, a sportive action, as unique, complex and often limited in time it may be, requires a selective gathering of information. This perception is often seen as a prerogative for action, it then takes the role of a passive collector of information. However, as mentioned by Gibson in 1979, the perception-action relationship should not be considered sequential but rather as a coupling: we perceive to act but we must act to perceive. There would thus be laws of coupling between the informational variables available in the environment and the motor responses of a subject. In other words, athletes have the ability to directly perceive the opportunities of action directly from the environment. Whichever school of thought considered, VR offers new perspectives to address these concepts by complementary using real time motion capture of the immersed athlete.

In addition to better understanding sports and interaction between athletes, VR can also be used as a training environment as it can provide complementary tools to coaches. It is indeed possible to add visual or auditory information to better train an athlete. The knowledge found in perceptual experiments can be for example used to highlight the body parts that are important to look at to correctly anticipate the opponent's action.

4.3. Crowds

Crowd simulation is a very active and concurrent domain. Various disciplines are interested in crowds modeling and simulation: Mathematics, Cognitive Sciences, Physics, Computer Graphics, etc. The reason for this large interest is that crowd simulation raise fascinating challenges.

At first, crowd can be first seen as a complex system: numerous local interactions occur between its elements and results into macroscopic emergent phenomena. Interactions are of various nature and are undergoing various factors as well. Physical factors are crucial as a crowd gathers by definition numerous moving people with a certain level of density. But sociological, cultural and psychological factors are important as well, since crowd behavior is deeply changed from country to country, or depending on the considered situations.

On the computational point of view, crowd push traditional simulation algorithms to their limit. An element of a crowd is subject to interact with any other element belonging the same crowd, a naive simulation algorithm has a quadratic complexity. Specific strategies are set to face such a difficulty: level-of-detail techniques enable scaling large crowd simulation and reach real-time solutions.

MimeTIC is an international key contributor in the domain of crowd simulation. Our approach is specific and based on three axis. First, our modeling approach is founded on human movement science: we conducted challenging experiment on the motion of groups. Second: we developed high-performance solutions for crowd simulation. Third, we develop solutions for realistic navigation in virtual world to enable interaction with crowds in Virtual Reality.

4.4. Interactive Digital Storytelling

Interactive digital storytelling, including novel forms of edutainment and serious games, provides access to social and human themes through stories which can take various forms and contains opportunities for massively enhancing the possibilities of interactive entertainment, computer games and digital applications. It provides chances for redefining the experience of narrative through interactive simulations of computer-generated story worlds and opens many challenging questions at the overlap between computational narratives, autonomous behaviours, interactive control, content generation and authoring tools.

Of particular interest for the Mimetic research team, virtual storytelling triggers challenging opportunities in providing effective models for enforcing autonomous behaviours for characters in complex 3D environments. Offering both low-level capacities to characters such as perceiving the environments, interacting with the environment and reacting to changes in the topology, on which to build higher-levels such as modelling abstract representations for efficient reasonning, planning paths and activities, modelling cognitive states and behaviours requires the provision of expressive, multi-level and efficient computational models. Furthermore virtual storytelling requires the seamless control of the balance between the autonomy of characters and the unfolding of the story story through the narrative discourse. Virtual storytelling also raises challenging questions on the conveyance of a narrative through interactive or automated control of the cinematography (how to stage the characters, the lights and the cameras). For example, estimating visibility of key subjects, or performing motion planning for cameras and lights are central issues for which have not received satisfactory answers in the litterature.

4.5. Biomechanics and Motion Analysis

Biomechanics is obviously a very large domain. This large set can divided regarding to the scale at which the analysis is performed going from microscopic evaluation of biological tissues' mechanical properties to macroscopic analysis and modeling of whole body motion. Our topics in the domain of biomechanics mainly lies within this last scope.

The first goal of such kind of research projects is a better understanding of human motion. In MimeTic, this has been done in three different situations: some everyday motions of lambda subject, locomotion of pathological subjects and sports gesture.

In the first set, we have studied how subjects maintain their balance in highly dynamic conditions. Until now, balance havec nearly always been considered in static or quasi-static conditions. The knowledge of much more dynamic cases still has to be improved. Our approach has demonstrated that first of all, the question of the parameter that will allow to do this is still open. We have also taken interest into collision avoidance between two pedestrian. This topic includes the research of the parameters that are interactively controlled and the study of each one's role within this interaction.

When patients, in particular those suffering from central nervous system affection, cannot have an efficient walking it becomes very useful for practicians to benefit from an objective evaluation of their capacities. To propose such help to patients following, we have developed two complementary indices, one based on kinematics and the other one on muscles activations. One major point of our research is that such indices are usually only developed for children whereas adults with these affections are much more numerous.

Finally, in sports, where gesture can be considered, in some way, as abnormal, the goal is more precisely to understand the determinants of performance. This could then be used to improve training programs or devices. Two different sports have been studied: the tennis serve, where the goal was to understand the contribution of each segments of the body in ball's speed and the influence of the mechanical characteristics of the fin in fin swimming.

After having improved the knowledge of these different gestures a second goal is then to propose modeling solutions that can be used in VR environments for other research topics within MimeTic. This has been the case, for exemple, for the colision avoidance.

4.6. Autonomous characters

Autonomous characters are becoming more and more popular has they are used in an increasing number of application domains. In the field of special effects, virtual characters are used to replace secondary actors and generate highly populated scenes that would be hard and costly to produce with real actors. In video games and virtual storytelling, autonomous characters play the role of actors that are driven by a scenario. Their autonomy allows them to react to unpredictable user interactions and adapt their behavior accordingly. In the field of simulation, autonomous characters are used to simulate the behavior of humans in different kind of situations. They enable to study new situations and their possible outcomes.

One of the main challenges in the field of autonomous characters is to provide a unified architecture for the modeling of their behavior. This architecture includes perception, action and decisional parts. This decisional part needs to mix different kinds of models, acting at different time scale and working with different nature of data, ranging from numerical (motion control, reactive behaviors) to symbolic (goal oriented behaviors, reasoning about actions and changes).

In the MimeTIC team, we focus on autonomous virtual humans. Our problem is not to reproduce the human intelligence but to propose an architecture making it possible to model credible behaviors of anthropomorphic virtual actors evolving/moving in real time in virtual worlds. The latter can represent particular situations studied by psychologists of the behavior or to correspond to an imaginary universe described by a scenario writer. The proposed architecture should mimic all the human intellectual and physical functions.

5. Software

5.1. HPTS++: Hierarchical Parallel Transition System ++

Participants: Stéphane Donikian [contact], Fabrice Lamarche [contact].

HPTS++ is a platform independent toolkit to describe and handle the execution of multi-agent systems. It provides a specific object oriented language encapsulating C++ code for interfacing facilities and a runtime kernel providing automatic synchronization and adaptation facilities.

The language provides functionalities to describe state machines (states and transitions) and to inform them with user specific C++ code to call at a given point during execution. This language is object oriented and supports concepts such as polymorphism and inheritance (state machines and user defined C++ classes). The compilation phase translates a state machine in a C++ class that can be compiled separately and linked through static or dynamic libraries. The runtime kernel includes a scheduler that handles parallel state machines execution and that provides synchronization facilities such as mutual exclusion on resources, dead lock avoidance, notions of priorities and execution adaptation in accordance with resources availability.

HPTS++ also provides a task model. Thanks to this model, the user can describe primitive behaviors through atomic tasks and combine them with operators (sequence, parallelism, loops, alternatives...). Theses operators are fully dynamic. Hence they can be used at runtime to rapidly create complex behaviors.

5.2. MKM: Manageable Kinematic Motions

Participants: Richard Kulpa [contact], Franck Multon.

We have developed a framework for animating human-like figures in real-time, based on captured motions. This work was carried-out in collaboration with the M2S Laboratory (Mouvement, Sport, Santé) of the University Rennes 2.

In this software, we propose a morphology-independent representation of the motion that is based on a simplified skeleton which normalizes the global postural informations. This formalism is not linked to morphology and allows very fast motion retargetting and adaptation to geometric constraints that can change in real-time This approach dramatically reduces the post production time and allows the animators to handle a general motion library instead of one library per avatar.

The framework provides an animation library which uses the motions either obtenained from our off-line tool (that tranforms standard formats into our morphology-independent representation) or parameterized models in order to create complete animation in real-time. Several models are proposed such as grasping, orientation of the head toward a target. We have also included a new locomotion model that allows to control the character directly using a motion database.

In order to create realistic and smooth animations, MKM uses motion synchronization, blending and adaptation to skeletons and to external constraints. All those processes are performed in real-time in an environment that can change at any time, unpredictably.

All these features have been used to anticipate and control the placement of footprints depending on high level parameters. This link between control and behavior levels will be used for reactive navigation in order to have realistic motion adaptations as well as to deal with constrained environments.

5.3. TopoPlan: Topological Planner and Behaviour Library

Participant: Fabrice Lamarche [contact].

TopoPlan (Topological Planner) is a toolkit dedicated to the analysis of a 3D environment geometry in order to generate suitable data structures for path finding and navigation. This toolkit provides a two step process: an off-line computation of spatial representation and a library providing on-line processes dedicated to path planning, environmental requests...

TopoPlan is based on an exact 3D spatial subdivision that accurately identifies floor and ceiling constraints for each point of the environment. Thanks to this spatial subdivision and some humanoid characteristics, an environment topology is computed. This topology accurately identifies navigable zones by connecting 3D cells of the spatial subdivision. Based on this topology several maps representing the environment are extracted. Those maps identify obstacle and step borders as well as bottlenecks. TopoPlan also provides a runtime library enabling the on-line exploitation of the spatial representation. This library provides several algorithms including roadmap-based path-planning, trajectory optimization, footprint generation, reactive navigation and spatial requests through customizable spatial selectors.

TopoPlan behavior is a library built on top of TopoPlan and MKM providing several behaviors described thanks to the HPTS++ task model. Its goal is to provide a high level interface handling navigation and posture adaptation within TopoPlan environments. Provided behaviors include:

- A behavior handling fully planned navigation toward an arbitrary destination. This behavior precisely handles footprint generation within constrained environments such as stairs for instance.
- A behavior controlling an MKM humanoid to follow a trajectory specified by the user.
- A behavior controlling MKM to follow a list of footprints given by the user.

- A behavior adapting the humanoid posture to avoid collision with ceiling. This behavior runs in parallel of all other behaviors and adapts humanoid motion when needed without any user intervention.
- A behavior handling reactive navigation of virtual humans. This behavior plan a path to a given target and follows the path while avoiding collisions with other navigating entities.

Those behaviors have been built using the HPTS++ task model. Thus, they can be easily combined together or with other described behaviors through task operators.

6. New Results

6.1. Motion Sensing and analysis

6.1.1. Sensing human activity fo detecting falling motions

Participants: Franck Multon [contact], Richard Kulpa, Anthony Sorel, Edouard Auvinet.

Sensing human activity is a very active field of research, with a wide range of applications ranging from entertainment and serious games to personal ambient living assistance. MimeTIC aims at proposing original methods to process raw motion capture data in order to compute relevant information according to the application.

In personal ambient living monitoring, we have collaborated with University of Montreal, Department of Computer Science and Operations Research (DIRO) which main activity is biomedical engineering. A co-supervised student is addressing two complementary problems: detecting people falling in everyday environment and providing easy-to-use clinical gait analysis systems for early detection of potential risks of falling. These two problems have been addressed by reconstructing the visual hull of a subject according to synchronized classical of depth cameras. As visual hull is based on videos it's subject to occlusions which generally occur in natural environment, such as a room with furniture. We have adapted the classical visual hull algorithm in order to be less sensible to occlusions. We also have proposed an index based on 3D silhouette vertical distribution which enhance this property to tackle occlusion problems [1]. This index is based on a ratio: the volume above a given threshold divided by the total body volume. It has been successfully applied to dozens of falling scenarios involving natural occlusions with furniture. The second problem consists in extracting relevant indexes in gait that could enable clinicians to identify elderly people who have a risk of falling. Classical indexes are based on gait regularity and asymmetry in dual tasks protocols (such as walking while counting downward). 3D silhouettes intrinsically contain all the required information in a unique representation contrary to multi-point motion capture systems. However extracting the relevant information from 3D volumes is complex. We have proposed an original approach based on statistical analysis of the volumes in order to compute indexes for gait asymmetry while simply using 3 depth-cameras (Microsoft Kinects) [1] (see figure 4).

In entertainment and serious games, the problem is different as we need to accurately now the action performed by the user in order to react in a convenient manner. Collaboration with Artefacto Company enabled us to develop such motion recognition methods in serious games scenarios. Given motion capture data provided by an optical motion capture system lead to large state vectors in which the relevant information is hidden. Mixture of Gaussians is generally used as an input of Hidden Markov Models to recognize a motion according to this raw data. To simplify, features are generally introduced in order to capture the relevant geometrical property of the motion with either general information (such as joint angles or Cartesian positions) or application-specific information. The former type of information has the advantage to be generic but leads to recognizers that are very sensitive to style and morphology variations. We have proposed a new generic feature based on morphology-independent representation that enables to tackle this problem (submitted to Eurographics2012). The recognition rate is above 75% for very similar upper-limb motions (see figure 5) while classical methods fail to recognize the same motions (recognition rate below 50%).

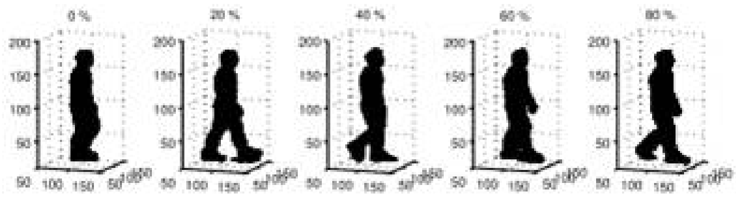

Figure 4. 3D silouhettes reconstructed with three depth-cameras in order to analyze gait asymmetry.

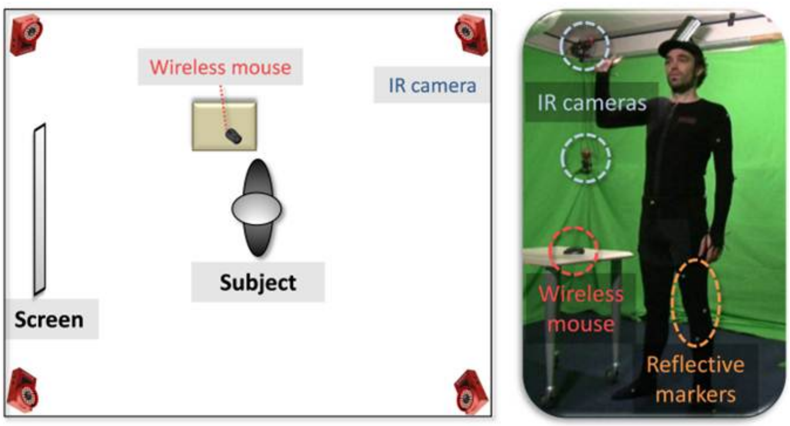

Figure 5. The motion of a user equiped with reflective markers is automatically recognized with a HMM system based on morphology-independent features.

6.1.2. *The Joyman: a novel immersive locomotion device for virtual environments*

Participant: Julien Pettré [contact].

We proposed a novel interface called Joyman, designed for immersive locomotion in virtual environments [18]. Whereas many previous interfaces preserve or stimulate the users proprioception, the Joyman aims at preserving equilibrioception in order to improve the feeling of immersion during virtual locomotion tasks. The proposed interface is based on the metaphor of a human-scale joystick. The device has a simple mechanical design that allows a user to indicate his virtual navigation intentions by leaning accordingly. We also propose a control law inspired by the biomechanics of the human locomotion to transform the measured leaning angle into a walking direction and speed - i.e., a virtual velocity vector. We aim at using this interface to enable natural interaction with virtual humans with low-cost devices. The Joyman is patented and was presented at the Emerging Technologies, Siggraph Asia, Hong-Kong [20].

These are joint results with the VR4i team (Anatole Lécuyer and Maud Marchal).

6.2. VR and Sports

Participants: Richard Kulpa, Benoit Bideau [contact], Brault Sébastien, Burns Anne-Marie.

In the past, we have worked on the interaction between two opponents in handball. We have designed a framework to animate virtual throwers in a reality center and to analyze the gestures of real goalkeepers whose objective was to intercept the corresponding virtual balls. This VR framework was then validated by showing that behaviors in real and virtual environment were similar. These works have been extended by using perception-action coupling and perception-only studies to evaluate the anticipation of opponents. In order to evaluate the importance of perceived parameters, the ball and/or the character animation was successively hidden to determine their importance and the same kind of study was done on the graphical level of details.

These works have been extended to the study of deceptive movements and gaps evaluation in rugby. Combining perceptual analysis based on the use of cutoffs with biomechanical analysis, we have extracted important kinematic information that could explain differences between experts and novices. Indeed, thanks to the cutoffs, it is possible to determine how early each of these two levels of practice can perceive the correct final direction of the opponent. Then this information is correlated to kinematical parameters of this player. Finally, we have embedding these knowledge on the evaluation of novices and expertsd to create models of rugby defenders. We are currently working on integrating these models in a VR experiment in which the real user is this time the attacker and our model the virtual defender.

Concurrently, studies are experimented to determine if VR can be used for training in sports [9]. The first step was to compare if trainees learned the same way in real situation, facing a video of the lesson or facing a virtual teacher that is animated from the motions of the real course. Based on evaluation of an expert, the results showed that the three groups evolved the same way and reached the same level of practice. The second step is then to have more experts to complete the evaluation but also to combine these results with objective analyses based on kinematics data.

This work is partially funded by the Biofeedback project (DGCIS "Serious Gaming" project) of the M2S laboratory, University Rennes 2. Its goal was to create a training tool that can be used and configured by coaches in order to train athletes to repetitive motions such as katas in karate. The evaluation is made by an automatic module that compares the kinematics of the trainee to a database of expert movements.

6.3. Crowds

Participants: Julien Pettré [contact], Richard Kulpa, Anne-Hélène Olivier, Samuel Lemercier, Yijiang Zhang, Jonathan Perrinet.

6.3.1. Perception of collision in crowds

We designed a level-of-detail (LOD) selection function to determine where collision avoidance constraints in crowd simulation can be relaxed without being perceived by spectators [4]. Collision avoidance is probably the most time consuming parts of crowd simulator. However, when only believable results are required, we argue that visually similar results can be obtained a low computational costs based on macroscopic crowd simulation. Based on a perception study, we determined the conditions for collision to be or not to be detected. We discovered that the camera tilt angle was playing a great effect on perception, whereas distance to camera (usually used in previous works) was only the third most important factor to be considered.

6.3.2. Mixed Reality Crowds

In the task of making virtual crowds and real people interact together, we explore a mixed reality solution [22]. The seamless integration of virtual characters into dynamic scenes captured by video is a challenging problem. In order to achieve consistent composite results, both the virtual and real characters must share the same geometrical space and their interactions must adhere to the physical coherence criteria. One essential question is how to detect the motion of real objects - such as real characters moving in the video - and how to steer virtual characters accordingly to avoid unrealistic collisions. We propose an online solution. First, by analysis of the input video, the motion states of the real objects are recovered into a common world 3D coordinate system. Meanwhile, a simplified accuracy measurement is defined to represent the confidence of the motion estimate. Then, under the constraints imposed by the real dynamic objects, the motion of virtual characters are accommodated by a uniform steering model. The final step is to merge virtual objects back the real video scene by taking into account visibility and occlusion constraints between real foreground objects and virtual ones.

6.3.3. Experiments on crowds

Evaluating crowd simulation models is a difficult task. In the frame of the ANR PEDIGREE project, we put in a lot of effort to perform experiments on groups of walking people in order to dispose of a reference database on groups motion. In order to obtain high-quality data, we measure people locomotion by using optoelectronic motion capture systems. In 2011, we starting obtaining detailed analysis on such motion after large efforts on motion analysis and processing. We had to develop dedicated reconstruction techniques because of the challenging conditions in which we performed our motion capture [12]. We submitted two papers on following modeling and simulation stages (submitted to Eurographics 2012 and Physical Review E).

6.4. Interactive Virtual Cinematography

Participants: Marc Christie [contact], Christophe Lino.

The domain of Virtual Cinematography explores the operationalization of rules and conventions pertained to camera placement, light placement and staging in virtual environments. In 2011, two major challenges were tackled (i) the proposition of intelligent interactive assistants integrating users in the process of selecting viewpoints and editing a virtual movie, with the capability of adapting to the user choices, and (ii) the design and implementation of evaluation functions for precisely ranking the quality of viewpoints of a virtual 3D environment.

Our intelligent assistant is designed around (i) an intelligent cinematography engine that can compute, at the request of the filmmaker, a set of suitable camera placements (called suggestions) for starting a shot, representing semantically and cinematically distinct choices for visualizing the current narrative, considering established cinema conventions of continuity and composition along with the filmmaker's previous selected suggestions, and also his or her manually crafted camera compositions, by a machine learning component that adapts shot editing preferences from user-created camera edits, (ii) a user interface, where the suggestions are presented as small movie frames, arranged in a grid whose rows and columns correspond to visual composition properties of the suggested cameras, and (iii) a motion-tracked camera system that makes the user able of modifying the low-level parameters of the camera in shots in the same way a real operator would. The result of this work [16] is a novel workflow based on interactive collaboration of human creativity with automated intelligence that enables efficient exploration of a wide range of cinematographic possibilities, and rapid production of computer-generated animated movies. A full prototype has been built and demonstrated at ACM Multimedia conference [15] as well as ParisFX conference. A patent protecting this technology is currently under evaluation [25].

The second challenge is related to the design of efficient and precise metrics for measuring the quality of viewpoints. For efficiency, we have proposed parallel GPU-based evaluation techniques for the estimation of multiple viewpoints [8] coupled within a Genetic Algorithm (Swarm Particle Optimization) to rapidly explore the space of possible viewpoints. For preciseness, we have designed a large range of quality functions relative to screen composition and transition between shots, and employed these functions to either automatically generate movies from actions occuring in the virtual environment [13] or interactively generating movies by letter the users select best shots and best transitions between shots [14].

Figure 6. Director's Lens: a new workflow for interactive virtual cinematography. For a spatial partition analysis of a 3D environment, our tools automatically generates ranges of viewpoint suggestions following classical cinematographic conventions. Cameramen then select the suggestions and refine them using a 6DOF tracked device.

Finally we have been exploring the use of tactile devices to the interactive construction of narratives following Prop's computational model of stories [10].

6.5. Biomechanics and Motion Analysis

6.5.1. Balance in highly dynamic situations

Participants: Franck Multon [contact], Ludovic Hoyet.

Balance is a key problem in humans as people stand on two feet which leads to a small base of support area compared to the overall body volume. This unstable state has been widely analyzed in static situation but is still difficult to understand when velocity and acceleration reach ineligible values. We thus have proposed an experimental protocol in order to evaluate if criteria published in the literature for specific motions could be generalized to any dynamic motions (see figure 7). To this end, each studied criterion was tested on various dynamic motions and the number of false falling alarms was reported in each case: the number of frames where the criterion detects loss of balance while the subject is actually balanced. The tested criteria where: the projection of the center of mass on the ground which should remain in the base of support, the Zero Moment Point widely used in robotics, the Zero Rate of Angular Momentum, the Foot Rotation Index and the extrapolated center of mass which was introduced in biomechanics recently. The results demonstrate that none of the criteria succeeded in correctly predicting loss of balance in highly dynamic motions [7]. It thus demonstrate the need to continue some fundamental work on this topic which is a key problem in many applications, including robotics, detection and prevention of falls in the Elderly, understanding performance in sports, improving realism in virtual human simulation...

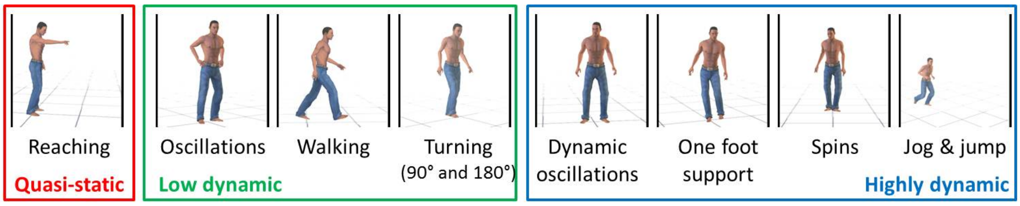

Figure 7. Dynamic motions that have been used to evaluate balance criteria published in previous works.

6.5.2. Interaction strategies between two walkers to avoid collision

Participants: Armel Crétual, Julien Pettré [contact], Anne-Hélène Olivier, Jan Ondrej, Antoine Marin.

In the everyday life situation where two humans walk in the same nearness, each can be considered as a moving obstacle for the other one. They adapt their locomotion with respect to this external disturbance to avoid any collision. Collision avoidance between two humans has been largely neglected in the literature despite it lets us expect specific interactions. The main question we raised was to identify the conditions that induce avoidance manoeuvres in locomotor trajectories: what are the relations between the respective positions and velocities which induce motion adaptations? To answer this question, we proposed an original experiment: thirty participants were asked to walk two-by-two in a motion captured area. We assigned them locomotion tasks in order to provoke varied situations of potential future collisions (see figure 8a). Following the hypothesis of a reciprocal interaction, we suggested a variable which is common to both of the walkers, the Minimum Predicted Distance (MPD), to predict the actual presence of physical interactions as well as to describe their properties. At each instant t, MPD was computed as the distance the walkers would meet if they did not perform motion adaptation after this instant t. Results showed that walkers adapted their motions only when required, i.e., when initial MPD was too low (<1m). We concluded that human walkers are able to accurately estimate future crossing distance and to mutually adapt it. The evolution of MPD enabled decomposing collision avoidance into 3 successive phases: observation, reaction, and regulation (see figure 8b). Respectively, these phases corresponded to periods of time when, first, MPD was constant, second, increased to acceptable values by motion adaptation and, third, reached a plateau and even slightly decreased. This final phase demonstrates that collision avoidance is actually performed with anticipation. Future work is needed to inspect individual motion adaptations and to relate them with variation of MPD.

6.5.3. Quantification of pathological gait in adults

Participants: Armel Crétual [contact], Kristell Bervet.

Quantifying gait deviation is still a challenge in adults patient follow-up within a rehab process. This quantification can be done on several levels. Among them, the most useful for practicians are surely kinematics and muscular activation. On the first one, Gillette Gait Index (GGI) has now become a common tool in rehabilitation centers to assess gait abnormalities. However, one limitation of this index is that it is based on some peak values and is thus sensitive to measurement noise. A new index, the Gait Deviation Index (GDI) which is based on joints angles patterns has been developed by the same team to avoid this problem. Nevertheless, both of them have only been validated in children with cerebral palsy. On the second level, no satisfaying global index has yet been developed. The first part of our study was to validate the GDI in adults.

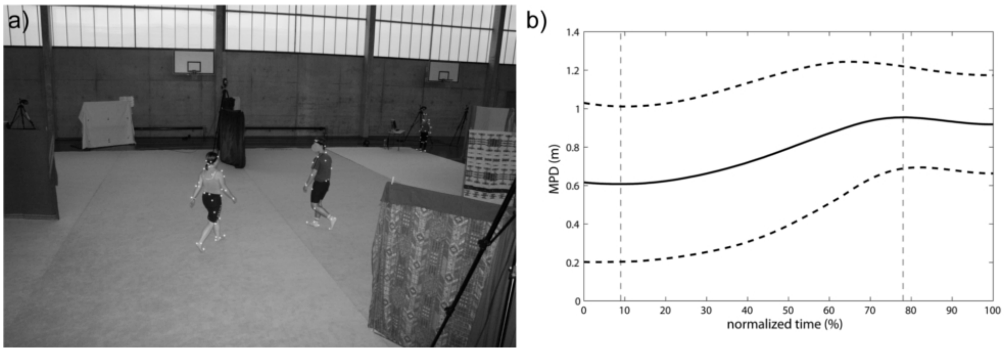

Figure 8. a)Experimental set-up to study collision avoidance between 2 walkers. b) Mean MPD evolution for trials for which initial MPD is below 1m. Interaction follows 3 successive phases: observation, reaction and regulation phases. Normalized time was computed between the time when participants were able to see each other to the time they crossed.

From a database of 74 healthy subjects and 48 patients we did demonstrate that GDI is a relevant index to quantify kinematic gait pattern in adults. Then, we developed a new index called KeR-EGI (for Kerpape-Rennes EMG-based Gait Index) which accounts for the muscular activation patterns of patients. There also, results were conclusive relying on a good correlation between GDI and KeR-EGI. Finally, our recommendation to practicians was to use both of these two index as they account for complementary aspects of pathology. This allow to better understand if gait disorder is more due to neurological injury or on the opposite to mechanical constraints such as joint stiffness.

6.5.4. Modeling gesture in sports: tennis serve

Participants: Nicolas Bideau [contact], Guillaume Nicolas, Benoit Bideau, Caroline Martin, Richard Kulpa.

Most experimental studies on tennis focus on the segmental coordination in connection with the ball speed, but do not consider the resulting traumatisms. To this end, we currently develop an inverse dynamics modeling approach, based on muskuloskeletal parameters. As a fist step to this work, we calculated the joint constraints on the upper limb in the tennis serve, for professional and regional players. Eleven high level, professional players were compared to seven regional players during this specific motion. Each player was equiped with 42 reflectiver markers and tennis serve was analyzed using an optoelectronical system composed of 12 infrared cameras cadenced at 300Hz. For each player, values of force, power and internal work (in absolute value) were calculated for the three joints (shoulder, elbow, wrist) using a musculoskeletal model. The results showed that professional players produced higher power and internal work for each joint in comparison with the regional players. Results also showed a decrease in the values of internal work from the distal (wrist joint) to the proximal joint (shoulder joint). These results may explain shoulder pain in tennis, which is commonly depicted for high-level players in epidemiological studies. A first perspective to this work is to better take individual parameters (inertia, muscle parameters, pre-constraint, etc.) into account. Another perspective is to test various objective functions in order to predict which parameter is optimized during tennis serve.

6.5.5. Modeling gesture in sports: fin swimming

Participants: Nicolas Bideau [contact], Guillaume Nicolas, Benoit Bideau, Richard Kulpa.

In swimming, experimental approaches are commonly used to analyze performance. However, due to obvious limitations in experimental approaches (impossibility to standardize any situations etc.), it is difficult to characterize surrounding fluid. To overcome this limitation, we currently develop analysis, modeling and simulation of aquatic locomotion, using CFD computer simulation and new methods based on animation of virtual characters.

A first application of this topic enables to evaluate the influence of swim fin flexibility on efficiency during swimming based on a CFD structure interaction model. Finite elements simulations are carried out for various material properties and various prescribed kinematics. Besides the significant effect of flexibility on propulsive forces, the results indicate that the propulsive efficiency is greatly influenced by the stroke frequency and the initial angle of attack. For the selected material properties, the results show that efficiency increases from 3.6 percents to 11.9 percents when the stroke frequency is increased from 0 to 1.7 Hz. Moreover efficiency is clearly increased from 5.0 percents to 24.2 percents when increasing the angle of attack from 0 to 45 degrees. Therefore, an interesting prospect of the present work could be an enhancement of the design of better performing swim fins.

A second application of this topic related to aquatic propulsion deals with a new method to evaluate cross-sectional area based on computer animation of swimming. Indeed, reducing cross sectional area (CSA) during starts and turns is a key part of performance optimisation. Different methods have been used to obtain this parameter without any standard: total human body volume to the power 2/3, wetted area or frontal area based on planimetry technique (PT). These different methods can lead to discrepancies in drag values. Recently, we used two synchronized camcorders to evaluate drag parameters during the different phases of an undulatory stroke cycle.

However, such a technique needs accurate synchronization and calibration of the different camcorders views. The aim of this study is to provide a new method based on animation of virtual characters to obtain instantaneous cross-sectional area in an undulatory stroke cycle. Its main advantage is to obtain cross-sectional area as well as biomechanical analysis with a single camcorder in a sagittal plan and without space calibration. From this, we intend to better understand swimming hydrodynamics and the way CSA influences active drag. More generally, this approach has been designed to provide new practical insights into swimming analysis protocols.

6.6. Path planning and environment analysis

6.6.1. Space-Time planning in dynamic environments

Participants: Fabrice Lamarche [contact], Thomas Lopez.

When automatically populating 3D geometric databases with virtual humanoids, modeling the navigation behavior is essential since navigation is used in most exhibited behaviors. In many application fields, the need to manage navigation in dynamic environments arises (virtual worlds taking physics laws into account, numerical plants in which step stools can be moved,...). This study focuses on the following issue: how to manage the navigation of virtual entities in such dynamic environments where topology may change at any time i.e. where unpredictable accessibility changes can arise at runtime. In opposition to current algorithms, movable items are not only considered as obstacles in the environment but can also help virtual entities in their navigation.

The proposed algorithm [17] splits that problem into two complementary processes: a topology tracking algorithm and a path planning algorithm. The aim of the topology tracking algorithm is to continuously detect and update topological relations between moving objects i.e. accessibility or obstruction, while storing temporal information when recurring relations are observed. The path planning algorithm uses this information to plan a path inside the dynamic environment. The coupling of those algorithms endows a virtual character with the ability to immediately use inserted / moved object to reach previously unreachable locations. Moreover, this algorithm is able to find a path through moving platforms to reach a target located on a surface that is never directly accessible.

6.6.2. Automated environment analysis

Participants: Fabrice Lamarche [contact], Carl-Johan Jorgensen.

To populate a virtual environment, modeling the navigation behavior is crucial. This behavior relies on the ability of planning a path inside a complex environment, which itself relies on an adequate representation of the environment structure. Most often, virtual environments are represented has 3D databases that are analyzed to produce data structures that are suitable for path planning and navigation. However, without any user intervention, those data structures lack of information about the nature of identified navigable zones that are crucial for navigation credibility.

We proposed an environment analysis algorithm [11] that automatically extracts a meaningful spatial representation of 3D virtual environments, suitable for spatial reasoning. This algorithm automatically differentiates indoor, outdoor and covered parts of the environment. It separates buildings into floors linked by stairs and represent floors as rooms linked by doorsteps. On this basis, we propose a natural hierarchical representation of the environment. This representation is used for spatial reasoning including zone selection and multi-criterion path planning that enhances path credibility.

7. Contracts and Grants with Industry

7.1. ANR SignCom: Sign-Based Communication Between Real and Virtual Agents

Participants: Franck Multon [contact], Stéphane Donikian.

The SignCom project aims to improve the quality of real-time interaction between humans and virtual agents by exploiting natural communication modalities such as gestures, facial expressions, and gaze direction. Using structured and coded French Sign Language signs, the real and virtual humans are able to converse with each other. This project is funded by the ANR ("Audiovisuel et Multimedia" call in 2007) and is leaded by VALORIA (University Bretagne Sud). The partners are: IRIT-TCI in Toulouse, M2S Lab in University Rennes2, Polymoprh company in Rennes and Websourd company in Toulouse.

MimeTIC was involved in three main parts:

- designing a database of motion capture data for French Sign Language gestures, according to a scenario defined by the other partners. This task involves gathering information from various devices so that the face, gingers and body motions are catured and gathered in a unique file. We thus have developed a specific experimental platform based on the Vicon-MX (product of Oxford Metrics) motion capture system, the 5-DT glove (product of Fifth Dimension Technologies), and FaceLAB (product of seeingmachines). We thus have developed specific algorithm to coordinate and make the fusion with all the data (which were recorded with various sampling frequencies). This work has been performed in close collaboration with M2S Lab. The resulting database if used both for gesture recognition and motion synthesis.
- developing a dialog manager which is able to use information provided by gesture recognition, analyze the sentence, find the relevant answer to the user and then call the motion synthesis module. This dialog manager is also used for integration of the contributions of the other partners.
- proposing an innovative gesture recognition that is able to address the intrinsic variability of gestures used in sign language: variability of the users and styles, but also variability in space and speed. We thus have proposed a machine-learning approach in three stages which enables us to recognize more than 90% of the 70 gestures involved in the scenario. This work has been performed in close collaboration with M2S Lab and State Key Lab in CAD&CG (Zheijiang University, China).

The SignCom project ends in December 2011.

7.2. ANR iSpace&time

Participants: Fabrice Lamarche [contact], Julien Pettré, Marc Christie, Carl-Johan Jorgensen.

The iSpace&Time project is founded by the ANR and gathers six partners: IGN, Lamea, University of Rennes 1, LICIT (IFSTAR), Telecom ParisTech and the SENSE laboratory (Orange). The goal of this project is the establishment of a demonstrator of a 4D Geographic Information System of the city on the web. This portal will integrate technologies such as web2.0, sensor networks, immersive visualization, animation and simulation. It will provide solutions ranging from simple 4D city visualization to tools for urban development. Main aspects of this project are:

- Creation of an immersive visualization based on panoramic acquired by a scanning vehicle using hybrid scanning (laser and image).
- Fusion of heterogeneous data issued by a network of sensor enabling to measure flows of pedestrians, vehicles and other mobile objects.
- Use of video cameras to measure, in real time, flows of pedestrians and vehicles.
- Study of the impact of a urban development on mobility by simulating vehicles and pedestrians.
- Integration of temporal information into the information system for visualization, data mining and simulation purpose.

The mimetic team is involved in the pedestrian simulation part of this project. This project started in 2011 and will end in 2013.

7.3. Biofeedback

Participants: Richard Kulpa [contact], Franck Multon, Anthony Sorel, Emmanuel Badier, Antoine Marin, Anne-Marie Burns.

The Biofeedback project aims at creating a training tool that can be used and configured by coaches in order to train athletes to repetitive motions such as katas in karate (figure 9). This project is funded by the DGCIS ("Serious Gaming" call) and is leaded by the M2S laboratory (University Rennes 2). The industrial partner of this project is the Artefacto society.

Figure 9. Biofeedback project.

The training platform proposed in the Biofeedback project allows the training of athletes to repetitive motions. Even if the application is made on Kata in Karate and Dance, all the system can be used in other sport applications. It is based on a virtual coach that shows the movement to perform but also evaluates the errors made by the trainee and then proposes different stages of learning to help the trainee to improve his skills.

The training platform allows then the capture the user's movement, the visualization of his motion and finally to evaluate it to determine the errors made (temporal and spatial errors). The project is thus based on 4 parts:

- Motion capture. The goal is to propose a low-cost motion capture system. To be usable by a wider audience, the system must be cheap and easy to use without complex calibration.
- Avatar animation from low quality captured data. Real-time motion capture leads to motion artifacts. A real-time reconstruction of the movement is then necessary.

+ Gesture evaluation. Each gesture to learn is associated with a database of experts movements that defines the perfect movement and the acceptable variability around this movement. This expert motion is also associated with biomechanical rules that are used to evaluate the temporal and spatial errors done by the trainee. These errors are then used to provide a score to the training system to choose the next level of training.
+ Transfer from virtual to real. A scientific evaluation of the training in virtual environments has been done to determine if the progress made in such system is really useful in real practice.

The Biofeedback project ends in December 2011.

7.4. ANR Pedigree

Participants: Julien Pettré [contact], Samuel Lemercier.

Pedigree is a national project funded by the French Research Agency (ANR) over for three years (Jan. 2009 to Dec. 2011). The project is leaded by Pierre Degond, professor at the University Paul Sabatier in Toulouse (III). Partners are: Institut de Mathématiques de Toulouse (IMT), Toulouse III University, Centre de Recherche sur la Cognition Animale (CRCA), Toulouse UIII University, Laboratoire de Physique Théorique (LPT), Paris-XI University, and the Mimetic team at INRIA-Rennes. 2011 is the third and last year for the Pedigree project.

The goals of the present project are the experimental and theoretical study of the formation of spatio-temporal structures within moving human groups and the development of realistic mathematical and simulation models of crowds based on these experimental data. This year, we have focused our efforts on analyzing unidirectional flow data. Analysis was conducted both at the microscopic and the macroscopic levels: we studied how individual control their locomotion from the motion of the people they follow, we also characterized some emergent phenomenon such as the formation and the damping of stop-and-go waves that propagates through the pedestrians flows. This analysis was jointly performed with LPT. A microscopic model of leader-follower behaviors has been deduced and carefully validated from experimental data. Collaboratively with IMT, a dedicated calibration procedure was elaborated. Three publications were prepared on this topic: one on data reconstruction, one on data analysis in submission to Physical Review E, and one on modeling and applications in submission to the Eurographics 2012 conference.

8. Partnerships and Cooperations

8.1. European Initiatives

8.1.1. FP7 Network of Excellence IRIS: Integrating Research in Interactive Virtual Storytelling

Participants: Stéphane Donikian [contact], Marc Christie [contact], Christophe Lino, Julian Joseph.

The IRIS project (Integrating Research in Interactive Storytelling) is a 3-year Network of Excellence project funded by the European Commission (FP-7 Grant Agreement 231824), from Jan. 2009 to Dec. 2011. The project gathers 10 academic partners: University of Teeside (project coordinator UK), INRIA (FR), Fachhochschule Erfurt (DE), TECFA Geneve (CH), Vrije Universiteit Amsterdam (NL), Universitat Augsburg (DE), Université La Rochelle (FR), OFAI Vienne (AT) and Newcastle University (UK).

IRIS (Integrating Research in Interactive Storytelling) aims at creating a virtual centre of excellence that will be able to achieve breakthroughs in the understanding of interactive storytelling and the development of corresponding technologies. It is organised around four major objectives:

- To extend interactive storytelling technologies in terms of performance and scalability, so that they can support the production of actual interactive narratives
- To make the next generation of interactive storytelling technologies more accessible to authors and content creators of different media backgrounds (scriptwriters, storyboarders, game designers)
- To develop a more integrated approach to interactive storytelling technologies, achieving a proper integration with cinematography
- To develop methodologies to evaluate interactive storytelling systems as well as the media experience of interactive narrative

8.1.2. FP7 STREP Fet-Open Tango

Participants: Julien Pettré [contact], Jonathan Perrinet, Anne-Hélène Olivier.

The goal of the TANGO project is to take some familiar ideas about affective communication one radical step further by developing a framework to represent and model the essential interactive nature of social communication based on non-verbal communication with facial and bodily expression. Indeed, many everyday actions take place in a social and affective context and presuppose that the agents share this context. But current motion synthesis techniques, e.g. in computer graphics, mainly focus on physical factors. The role of other factors, and specifically psychological variables, is not yet well understood.

In 2011, we conducted an experimental study on the effect of emotions during physical interactions between people. We focused the case of locomotion. We studied various situations of interaction such as collision avoidance or walking together. We asked professional actors to play such situation under conditions of emotions. Preliminary results show some emergent behavior, such as some leader-follower relations between people that depend on emotional context.

8.2. International Initiatives

8.2.1. INRIA International Partners

- University of North Carolina at Chapel Hill, GAMMA Group, with Professor Ming Lin and Dinesh Manocha: exchanges of master and PhD students on crowd simulation and motion planning for autonomous characters. Preparation of an INRIA Associated Team proposal for 2012.
- State Key Lab CAD&CG, Zheijiang Univ., China: 1-year stay of Xiubo Liang, PhD Student, in France to work on the gestures recognition for the French Sign Language.
- University of Montreal, Département d'informatique et de recherche opérationnelle (DIRO) with Jean Meunier: 1.5 years stay of Edouard Auvinet, a co-supervised PhD student who is working on falling detection and prevention through computer vision and simulation approaches.
- University of Barcelona, Event Lab, with Mel Slater: co-supervision of a PhD student (Anne-Marie Burns) who is working on using VR for serious training in sports.
- Queen's University Belfast, psychology school, Cathy Craig (ERC Grant): co-supervision of Sebastien Brault, PhD student who is working on analyzing perception-action coupling in duels using immersive systems.

- National Chengchi University, Taiwan with Professor Tsai-Yen Li: Exchange of students and researchers around Smart motion planning using semantic annotations to augment path planning capacities for characters and cameras.

8.2.2. Visits of International Scientists

- Invited professor: William Bares (Millsaps College, USA) for three months (ISTIC grant), on the topic of virtual camera tracking.

9. Dissemination

9.1. Animation of the scientific community

9.1.1. Scientific Community Animation

- F. Multon: **Leader** of the Mimetic research team
- F. Multon: **Member** of the European Society of Biomechanics, the ACM association, the IEEE association, the Computer Society association, the Eurographcis association, the European Society of Biomechanics, the French "Societe de Biomecanique", the French "Association Française de Realite Virtuelle", **Reviewer** Journal of Biomechanics, CASA internation conference, Computer Methods in Biomedical Engineering journal, Computer & Graphics journal, Eurographics 2011, IEEE International Symposium on Robot and Human Interactive Communication conference, IEEE TVCG journal, **Program Committee member** of ACM SIGGRAPH Asia (Sketches and posters), Motion in Games Conference MIG2011, SKILLS conference, **Scientific expert** for "Pole Productique de Bretagne", and Auteo association, in ergonomics, **Guest editor** of Presence - Mit Press, VR & Sports special issue: Benoit Bideau, Richard Kulpa, Franck Multon, **Program chair** of Simulation of Sports Motion co-located with CASA2011, **Session chairman** of "Modélisation musculo-squelettique" in ACAPS'2011 conference and "Analyses Biomécanique de la performance motrice" in ACAPS'2011.
- M. Christie: **Member** of Eurographics, AFIG and AFRV, **Member** of Program committee and Steering committee of Smartgraphics 2011, **Reviewer for** Eurographics 2011, Smartgraphics 2011, Foundations of Digital Games, IEEE Visualisation, Pervasive 2011, **Reviewer for journals** Computer Graphics Forum, Transactions on Visualisation and Computer Graphics, Transactions on Robotics, Computers and their Applications.
- R. Kulpa: **Guest editor** of Presence - Mit Press, VR & Sports special issue (with F. Multon and B. Bideau), **Organization committee** member of ACAPS 2011 conference, **Program chair** of "VR and Sports" Symposium with B. Bideau; **Program committee** of CGVCVIP 2011 conference; **Reviewer** of IEEE VR.
- F. Lamarche: **Reviewer** for Computer Animation and Virtual Worlds. **PhD Committee** of Hakim Soussi.
- J. Pettré: **Member** of ACM and IEEE associations, **Reviewer for** Siggraph, Siggraph Asia, Eurographics, Pacific Graphics, Computer Animation and Social Agents, ACM/Eurographics Symposium on Computer Animation, IEEE Transactions on Visualization and Computer Graphics, Computer Animation and Virtual Worlds, ICRA, VR, Journal of Computational Science, Computer Graphics Forum, Autonomous Robots, Motion in Game Conference, **Program Committee member** of Pacific Graphics, **Scientific expert** for ANR
- A. Crétual: **Reviewer** of Medical & Biological Engineering & Computing, Journal of Electromyography and Kinesiology, **Editorial Board** of Journal of Electromyography and Kinesiology, **PhD Committee** of Caroline Moreau

9.1.2. Courses in Universities

- M. Christie: User interaction (U. of Nantes), Programming on tactile surfaces and Android (U. of Nantes)
- R. Kulpa: Biomechanics and scientific programming, University Rennes 2, Computer Animation IUT Bordeaux 1.
- F. Lamarche: Computer Animation ESIR IN, AI for Video Games ESIR IN, Real Time Rendering and Computer Animation MASTER GL, IFSIC - MIT, ENS CACHAN/RENNES.
- F. Multon: Master of Computer Science Ifsic : Image and Motion; MASTER OF PHYSICAL EXERCISE University Rennes2
- A. Crétual: Master course on Sports or pathological Gesture analysis, Univ. Rennes 2

10. Bibliography

Publications of the year

Articles in International Peer-Reviewed Journal

[1] E. AUVINET, F. MULTON, A. SAINT-ARNAUD, J. ROUSSEAU, J. MEUNIER. *Fall detection with multiple cameras: An occlusion-resistant method based on 3D silhouette vertical distribution*, in "IEEE Transactions on Information Technology in Biomedicine", March 2011, vol. 15, n^{o} 2, p. 290-300 [*DOI :* 10.1109/TITB.2010.2087385], http://hal.inria.fr/hal-00640199/en.

[2] B. BIDEAU, R. KULPA, F. MULTON. *Special Issue: Virtual Reality and Sports Guest Editors' Introduction*, in "Presence: Teleoperators and Virtual Environments", February 2011, vol. 20, n^{o} 1, p. 3-4 [*DOI :* 10.1162/PRES_E_00029], http://hal.inria.fr/hal-00640251/en.

[3] A. CRETUAL, N. FUSCO. *Additional energetic cost due to belt speed variations when walking on a treadmill*, in "Journal of Electromyography and Kinesiology", June 2011, vol. 21, n^{o} 3, p. 551-556, http://hal.inria.fr/hal-00642462/en.

[4] R. KULPA, A.-H. OLIVIER, J. ONDREJ, J. PETTRÉ. *Imperceptible Relaxation of Collision Avoidance Constraints in Virtual Crowds*, in "ACM Transactions on Graphics (Proceedings of SIGGRAPH ASIA)", 2011, http://hal.inria.fr/hal-00642607/en/.

[5] A.-H. OLIVIER, R. KULPA, J. PETTRÉ, A. CRETUAL. *A step-by-step modeling, analysis and annotation of locomotion*, in "Computer Animation and Virtual Worlds", 2011, http://hal.inria.fr/hal-00642611/en.

[6] W. YOUNG, S. FERGUSON, S. BRAULT, C. CRAIG. *Assessing and training standing balance in older adults : A novel approach using the 'Nintendo Wii' Balance Board*, in "Gait and Posture", 2011, vol. 33, n^{o} 2, p. 303-305, http://hal.inria.fr/hal-00641505/en.

Articles in Non Peer-Reviewed Journal

[7] L. HOYET, F. MULTON. *Comparison of models of dynamic balance in biological motions*, in "Computer Methods in Biomechanics and Biomedical Engineering", August 2011, vol. 14, n^{o} S1, p. 183-184 [*DOI :* 10.1080/10255842.2011.594713], http://hal.inria.fr/hal-00640201/en.

International Conferences with Proceedings

[8] R. ABDULLAH, M. CHRISTIE, G. SCHOFIELD, C. LINO, P. OLIVIER. *Advanced Composition in Virtual Camera Control*, in "Smart Graphics", Bremen, Germany, A. BUTZ (editor), August 2011, n° 6815, p. 13-24 [*DOI :* 10.1007/978-3-642-22571-0_2], http://hal.inria.fr/hal-00646400/en.

[9] A.-M. BURNS, R. KULPA, A. DURNY, B. SPANLANG, M. SLATER, F. MULTON. *Using virtual humans and computer animations to learn complex motor skills: a case study in karate*, in "SKILLS", Montpellier, France, December 2011, http://hal.inria.fr/hal-00640208/en.

[10] Y.-T. CHANG, T.-Y. LI, S.-C. CHEN, M. CHRISTIE. *A Computer-aided System for Narrative Creation*, in "TERA International Conference on Education (TICE 2011)", Kaoshiung, Taiwan, Province Of China, December 2011, http://hal.inria.fr/hal-00646895/en.

[11] C. J. JORGENSEN, F. LAMARCHE. *From geometry to spatial reasoning : automatic structuring of 3D virtual environments.*, in "Motion In Games", Edimbourg, United Kingdom, J. M. ALLBECK, P. FALOUTSOS (editors), Lecture notes in computer sciences, Springer, November 2011, http://hal.inria.fr/hal-00639662/en.

[12] S. LEMERCIER, M. MOREAU, M. MOUSSAID, G. THERAULAZ, S. DONIKIAN, J. PETTRÉ. *Reconstructing motion capture data for human crowd study.*, in "Motion in Games", Edimbourg, United Kingdom, J. M. ALLBECK, P. FALOUTSOS (editors), Lecture notes in computer sciences, Springer, November 2011, http://hal.inria.fr/hal-00645213/en/.

[13] C. LINO, M. CHOLLET, M. CHRISTIE, R. RONFARD. *Automated Camera Planner for Film Editing Using Key Shots (poster)*, in "ACM Siggraph / Eurographics Symposium on Computer Animation", Vancouver, Canada, August 2011, http://hal.inria.fr/hal-00646404/en.

[14] C. LINO, M. CHOLLET, M. CHRISTIE, R. RONFARD. *Computational Model of Film Editing for Interactive Storytelling (poster)*, in "International Conference on Interactive Digital Storytelling", Vancouver, Canada, SPRINGER (editor), Lecture Notes in Computer Science, Interactive Storytelling, November 2011, vol. 7069, p. 305-308, http://hal.inria.fr/hal-00640124/en.

[15] C. LINO, M. CHRISTIE, R. RANON, W. BARES. *A Smart Assistant for Shooting Virtual Cinematography with Motion-Tracked Cameras (Démo)*, in "ACM Multimedia", Scottsdale, United States, November 2011, http://hal.inria.fr/hal-00646396/en.

[16] C. LINO, M. CHRISTIE, R. RANON, W. BARES. *The Director's Lens: An Intelligent Assistant for Virtual Cinematography*, in "ACM Multimedia", Scottsdale, United States, November 2011, http://hal.inria.fr/hal-00646398/en.

[17] T. LOPEZ, F. LAMARCHE, T.-Y. LI. *Space-time planning in dynamic environments with unknown evolution.*, in "Motion In Games", Edimbourg, United Kingdom, J. M. ALLBECK, P. FALOUTSOS (editors), Lecture notes in computer sciences, Springer, November 2011, http://hal.inria.fr/hal-00639664/en.

[18] M. MARCHAL, J. PETTRÉ, A. LÉCUYER. *Joyman: a Human-Scale Joystick for Navigating in Virtual Worlds*, in "IEEE Symposium on 3D User Interfaces 2011 (3DUI)", Singapour, Singapour, Mar 2011, http://hal.inria.fr/inria-00567437/en/.

[19] A. NGHIEM, E. AUVINET, F. MULTON, J. MEUNIER. *Contactless Abnormal Gait Detection*, in "EMBC", Boston, United States, IEEE Press, 2011, http://hal.inria.fr/hal-00640209/en.

[20] J. PETTRÉ, M. MARCHAL, O. SIRET, J.-B. DE LA RIVIÈRE, A. LÉCUYER. *Joyman: an Immersive and Entertaining Interface for Virtual Locomotion*, in "ACM SIGGRAPH Asia Emerging Technologies", Hong-Kong, Hong Kong, December 2011, http://hal.inria.fr/hal-00644256/en.

[21] L. TERZIMAN, M. MARCHAL, F. MULTON, B. ARNALDI, A. LÉCUYER. *Comparing Virtual Trajectories Made in Slalom Using Walking-In-Place and Joystick Techniques*, in "EuroVR / EGVE Joint Virtual Reality Conference", Nottingham, Royaume-Uni, Eurographics, 2011, http://hal.inria.fr/hal-00641371.

[22] Y. ZHANG, J. PETTRÉ, J. ONDREJ, Q. XUEYING, Q. PENG, S. DONIKIAN. *Mixed Reality Crowds: Online Inserting Virtual Characters into Dynamic Video Scenes*, in "CASA 2011", Chengdu, Chine, 2011, http://hal.inria.fr/hal-00645210/en/.

Scientific Books (or Scientific Book chapters)

[23] F. MULTON. *Sensing Human Walking: Algorithms and Techniques for Extracting and Modeling Locomotion*, in "Human Walking in Virtual Environments: Perception, Technology, and Applications", J. CAMPOS, A. LÉCUYER, Y. VISELL, F. STEINICKE (editors), Springer, 2012, http://hal.inria.fr/hal-00640205/en/.

[24] F. MULTON, A.-H. OLIVIER. *Cognition and biomechanics of walking*, in "Human Walking in Virtual Environments: perception, technology and applications", J. CAMPOS, A. LÉCUYER, Y. VISELL, F. STEINICKE (editors), Springer, 2012, http://hal.inria.fr/hal-00640204/en/.

Patents and standards

[25] W. BARES, C. LINO, M. CHRISTIE, R. RANON. *Director's Lens: Collaborative automated cinematography assistant for motion-tracked virtual cameras*, 2011, n° (under revision), http://hal.inria.fr/hal-00646418/en.